

the habits and food of young fishes, plankton work and experiments with weighted drift and bottles. Mr. James Johnstone writes on the spawning of the mussel (*Mytilus edulis*); Prof. Herdman on sea-fish hatching, and on oysters and disease: Mr. Charles A. Kohn on occurrence of iron and copper in oysters; Mr. R. S. Ascroft on mussels and mud-banks; and Messrs. F. W. Keeble and F. W. Gamble present a brief report on the physiology of colour-change in *Hippolyte* and other marine crustacea. This is the first complete year of Mr. Scott's work at the Piel hatchery, and of Mr. Johnstone's work at the laboratory. The laboratory attached to the hatchery is open, under certain conditions, to the use of *bona-fide* students and others desirous of prosecuting research. A glance at the above list of papers will show the variety and extent of the investigations that were undertaken last year.

THE scientific activity of the Société de Physique et d'Histoire naturelle de Genève during 1898 is evidenced by the survey of papers published in the *Archives* of the Society, given by Prof. Albert Rilliet in his presidential report just issued. In mathematics and astronomy M. René de Saussure contributed the results of a geometrical study of the movement of fluids, Prof. Gautier computations referring to the return of Tempel's periodic comet, and M. Pidoux observations of an occultation of Antares by the moon. In physics and chemistry M. Dumont gave an account of researches on the magnetic properties of iron and nickel, MM. Dutoit and Friderich described a method of indirectly calculating critical pressure, Prof. Amé Pictet gave an account of further researches on the synthesis of nicotine, and Prof. Soret described his investigations of the causes which produce left- and right-handed crystals in salts active in the crystalline state and inactive in solution. Although no positive results were obtained, the work is important from a statistical point of view. Among the subjects of papers in zoology, physiology, and medicine, were the development of butterflies, by M. Arnold Pictet; and the place of origin of vaso-motor nerves, and effects of currents of high frequency upon the frog, by Dr. Batelli. In botany, a paper by Mlle. Goldfluss on the functions of certain cells was communicated by Prof. Chodat. In physical geology, M. Ed. Sarasin described the records obtained by a limnimeter established at Lucerne during five months in 1897. The records show three distinct periods of oscillation. The results of a detailed inquiry into the constitution of Mont Blanc are given by Prof. Duparc in an important memoir just published by the Society. Finally, mention may be made of a paper by MM. Etienne Ritter and Delebecque on the lakes of the Pyrenees. A number of other papers were read before the Society during 1898, but those here mentioned will be sufficient to show the valuable character of the work accomplished.

THE additions to the Zoological Society's Gardens during the past week include two Mozambique Monkeys (*Cercopithecus pygerythrus*), a Sykes's Monkey (*Cercopithecus albicularis*) from East Africa, presented by Mr. Boyd Alexander; a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mrs. Herbert Peel; a Slow Loris (*Nycticebus tardigradus*) from Malacca, presented by Mr. W. H. St. Quintin; two Squirrel-like Phalangiers (*Petaurus sciureus*, ♂ & ♀) from Australia, presented by Mr. A. V. Willcox; four Dormouse Phalangiers (*Dromicia nana*) from Tasmania, presented by Dr. McDougall; a Greater Black-backed Gull (*Larus marinus*), a Lesser Black-backed Gull (*Larus fuscus*), European, presented by the Rev. W. B. Tracy; a Drill (*Cynocephalus leucocephalus*), a Kusimanse (*Crossarchus obscurus*), a Pardine Genet (*Genetta pardina*), a Home's Cinixys (*Cynixys homeana*), a Derbian Sternothera (*Sternotherus derbianus*) from West Africa, a Bell's Cinixys (*Cinixys belliana*) from Tropical Africa, a Common Zebra

(*Equus zebra*, ♂) from South Africa, a Grecian Ibex (*Capra oegagrus*, ♂), South-east European, a Two-wattled Cassowary (*Casuarius bicarunculatus*) from the Aroo Islands, deposited; two Larger Tree Ducks (*Dendrocygna major*) from India, purchased; a Mouflon (*Ovis musimon*, ♀) born in the Gardens.

OUR ASTRONOMICAL COLUMN.

COMET 1899 *a* (SWIFT).—This comet is now well situated for observation in the early morning, and has been frequently seen during the past week. Passing rapidly to the north-west, it will rise earlier every morning, and opportunities will be afforded of obtaining both photographic and visual records of its form and spectrum. The positions predicted by the ephemeris are so nearly correct that there is no possibility of mistaking the comet. As seen on several mornings at the Solar Physics Observatory, South Kensington, it appears to the unaided eye as bright as a star of the fourth magnitude, and, though possessing no tail, is sufficiently unlike a star in appearance to attract notice. With a telescope it is seen to consist of an irregular nucleus about 1' in diameter, surrounded by a much fainter nebulous mass some 10' in diameter. Photographs of the spectrum have been obtained showing six bands between D and H, the origins of which have not yet been deduced.

During the week the comet will pass from Pegasus into Lacerta, through a region devoid of conspicuous stars; but on the 17th it will be about 3° west of the second magnitude star α Andromedæ.

The following ephemeris is by Herr H. Kreutz in *Astr. Nach.* (Bd. 149, No. 3556).

Ephemeris for 12h. Berlin Mean Time.

1899.	R.A.	Decl.	Br.
	h. m. s.		
May 11 ...	23 26 28	+33 12'7"	1'66
12 ...	20 48	34 33'1"	
13 ...	14 41	35 36'8"	1'68
14 ...	8 2	37 23'9"	
15 ...	23 0 46	38 54'2"	1'71
16 ...	22 52 48	40 27'8"	
17 ...	44 2	42 4'2"	1'74
18 ...	22 34 21	+43 42'9"	

TEMPEL'S COMET (1873 II.).—The following ephemeris for this comet is by M. L. Schulhof in *Astr. Nach.* (Bd. 149, No. 3554):—

Ephemeris for 12h. Paris Mean Time.

1899.	R.A.	Decl.	Br.
	h. m. s.		
May 11 ...	19 0 46'1"	-4 15'3"	
12 ...	2 25'8"	4 11 42 ...	0'592
13 ...	4 5'2"	4 8 30	
14 ...	5 44'2"	4 5 29	
15 ...	7 22'7"	4 2 38	
16 ...	9 0'9"	3 59 59 ...	0'673
17 ...	10 38'7"	3 57 31	
18 ...	19 12 16'1"	-3 55 17	

The comet is moving slowly to the north-east, passing from Scutum Sobieski into the southern part of Aquila, being about 10° S.W. of α Aquilæ on the 18th.

A telegram just received from Kiel announces the first observation of this comet during this apparition, by Prof. Perrine at the Lick Observatory. Its position as measured was R.A. 18h. 52m. 58s. } 1899 May 6, 13h. 40'5m. Lick Mean Decl. - 4° 32' 19" } Time, and it is described as being faint.

The close agreement of these numbers with the computed data given in the ephemeris renders any revision of the latter unnecessary.

PROGRESS IN THE IRON AND STEEL INDUSTRIES.¹

THE announcement that Her Majesty the Queen will be graciously pleased to accept the Bessemer Medal for 1899, in commemoration of the progress made in the iron and steel industries during her reign, will be received with enthusiasm throughout the Empire. What the progress has been it will be

¹ Abstract of the presidential address to the Iron and Steel Institute, by Prof. Sir W. Roberts-Austen, K.C.B., D.C.L., F.R.S., delivered before the members of the Institute on May 4.

my privilege to indicate in this Address ; for your last President of the century, in bidding it a respectful farewell, must offer the best retrospective tribute he can to the grandest industry in the world's history.

This address will, therefore, be mainly devoted to the consideration of British efforts in connection with iron and steel. I shall hope on another occasion to pay homage to the services rendered in other countries to our branch of metallurgy, but in view of our autumn meeting last year at Stockholm, I cannot proceed further without making a brief reference to Sweden. To her scientific men our debt is great and of long standing, for we have profited by their labours from the eighteenth century until now. We appreciated the interest in our proceedings which was shown by the presence of His Majesty the King and the Royal Princes at our meetings in the Riddarhus. The gracious kindness of His Majesty during the magnificent reception at his palace of Drottningholm will never be forgotten by those of us who were present. The spontaneous warmth of our reception by the Swedish people also touched us deeply, and the memories of our visit will be handed down as traditions to future members of our Institute, who, in the days to come, will, we trust, again seek the aid of Sweden by supplementing the ores of our own possessions with those from within the Arctic circle.

From the technical point of view, as the eighteenth century closed, a new era in the metallurgy of iron had already begun. Abraham Darby had successfully introduced the use of coke in the blast-furnace ; James Watt had, by his powerful engines, much facilitated the production of blast, and had greatly stimulated the out-turn of pig iron. Nevertheless, the total annual production of pig iron in the year 1799 did not exceed some 150,000 tons. From the scientific point of view the situation was one of singular interest. The early writers held that good and bad qualities might be inherent in the iron itself. Pliny points out how greatly the properties of iron depend upon its treatment, but he thought that as for the kinds of iron, they were many and all were distinct, and the first difference arises from the diversity of the soil and climate where the mines are found. But Pliny's view survived far into the present century, and evidence of it lingered in the effective and graceful speech in which the Member for Merthyr proposed a vote of thanks to our first President on the delivery of his inaugural address. Mr. Fothergill said then that "thirty years ago the idea prevailed universally . . . that good iron was to be found in certain localities, and could be procured from no other place ; it was found good in one place and bad in another." He adds : "Enlightened progress of the last thirty years has shown that the quality of iron depends upon the alloy with which it is mixed."

Enduring as the old view as to the influence of locality was, an experimental basis for a more accurate one had been established very shortly before the present century began, and some, at least, knew that the properties of iron depended on the presence or absence of certain other elements. This position was clearly established by the great Swedish chemist, Bergman of Upsala, who had shown that carbon is the element to which steel and cast iron owe their distinctive properties. He had initiated the employment of calorimetric methods in determining the properties of iron and steel. He insisted that the real difficulty is to explain how it is that the presence of 0.5 per cent. of carbon in iron enables the metal to be hardened by quenching from a red heat, or, in his own expressive words, *Ceterum quomodo dimidia centesima, plumbaginem efficiens, tantum provocare possit differentiam, nodus est gordius haud facile solvendus*. Bergman, moreover, anticipated the later phases of modern research by claiming that iron is a polymorphic element, and plays the part of many metals. In this early view as to the allotropy of iron it should be remembered that in 1790 our countryman, James Keir, followed him closely by urging, before the Royal Society, that what we now call passive iron "is really a distinct form of iron, the alteration being produced without the least diminution of its metallic splendour or change of colour."

Clouet's celebrated experiment on the carburisation of iron by the diamond followed. Doubts, however, were not finally set at rest until 1815, when Pepys, a working cutler in London, excluded the possibility of the intervention of furnace gas. But, as soon as the present century had well turned, the industrial world was in possession of the fundamental fact that carbon is the element of dominant importance in relation to the metallurgy of iron. Well might Bergman express astonishment

at the action of carbon on iron. Startling as the statement may seem, the destinies of England throughout the century, and especially during the latter half of it, have been mainly influenced by the use of steel. Her steel rails seldom contain more than Bergman's half per cent. of carbon. Her ship-plates, on which her strength as a maritime power depends, contain less than half that amount. It is essential that the significance of this fact should be clearly understood. Our national existence has long depended on iron and steel. They have been the source of our wealth, one of the main elements of our strength, one cause of our maritime supremacy. Hardly a step of our progress or an incident of our civilisation has not, in one way or another, been influenced by the properties of iron or steel. It is remarkable that these properties have been determined by the relations subsisting between a mass of iron, itself protean in its nature, and the few tenths per cent. of carbon it contains. These properties are, it is true, modified either by the simultaneous presence of elements other than carbon, or by the thermal or mechanical treatment of the mass. The growth of our knowledge of the facts constitutes a large section of our scientific and industrial history. The question arises—Was our national progress delayed by the unreadiness of the technical world in England to take advantage of the facts that science had established?

If we consider the position from the point of view of two remarkable men who were looking for the dawn of the nineteenth century as we are for that of the twentieth, we shall, I think, be satisfied that our progress received no check from failure of industrial workers to assimilate the teaching of science. These men were Black and Cort. Of the scientific men then living, the greatest chemist was Black, Professor at the University of Edinburgh, whom Lavoisier had generously acknowledged as his master. Black fully recognised the importance of Bergman's work, and on his own part insisted on the importance of what would now be called the change in molecular energy as the physical basis on which the properties of iron and steel depend. Black, moreover, in his public lectures gave a singularly accurate description of the process of decarburising iron called "puddling," and devised by "a Mr. Cort," with the results of whose work Black was soon to become familiar. Considering how recent the knowledge of the meaning of oxidation really was at the time, Black's statements with regard to the theory of puddling are truly remarkable. Later on he furnished the Government with an elaborate report on the quality of the material obtained by puddling. He showed, by such mechanical tests as the experience of the time suggested, the superiority of puddled iron, and pointed out that it was more suitable than foreign iron for the appliances "on which," as he says, "the lives of our seamen and the safety of our ships have hitherto mainly depended."

At the end of the century we are justly proud of our colonial possessions, and are satisfied that the varied applications of iron and steel will enable us to knit together all parts of the empire. At the beginning of the century, Lord Sheffield, in his "Observations on the commerce of the American States," writing in the early days of Cort's process, shows that it would help to make British iron as cheap as the foreign, an event which he considered would be more advantageous to England than the possession of her American colonies. Black died in 1799, Cort survived till 1800, so that as the eighteenth century closed, the most eminent scientific man and the foremost practical metallurgist of the generation stood side by side. To Cort we owe the greatest technical advance the modern world had seen ; to Black the recognition of the importance of molecular energy in relation to metallurgical problems.

The production of pig iron in this country also received a great stimulus from the discovery by Mushet about the year 1800, that the large deposits of blackband ironstone could be utilised. The century opened with, in round numbers, an annual production of pig iron not exceeding 200,000 tons, of which less than one-third was converted into bars and other descriptions of wrought iron. The capital invested was under five millions, and employment was furnished for nearly 200,000 people.

Returning to the scientific aspect disclosed at the dawn of the century, the year 1803 was an eventful one for science. Nevertheless, the impulse given to research was not in the most favourable direction for the advancement of metallurgical art. The influence of a small proportion of carbon on iron had been recognised, but the quantitative relation between the iron and the carbon was only considered as bearing on the

nature of the product, and not at all from the point of view of chemical union. When, therefore, in 1803, Claude Louis Berthollet published his "Essai de Statique Chimique," it appeared that the action, of what for the moment I may be permitted to classify as the action of *traces* upon *masses*, was in a fair way to be elucidated for the following reason. Berthollet pointed out that "in comparing the action of bodies on each other which depends on their affinities and mutual proportions, the influence of mass has to be considered." Unfortunately in succeeding years the views of Prout, the courteous opponent of Berthollet, prevailed, mainly through the powerful aid of Dalton, who published also in 1803 his first table of atomic weights. Hence the phenomena which could not be attributed to fixed atomic proportions were set aside and usually neglected. Evidently the action of one-tenth per cent. of carbon on iron could not be explained by the aid of combining weights. The century was more than half over before a school of eminent chemists arose, who did not insist that matter is minutely granular, but in all cases of change of state made calculations on the basis of work done, viewing internal energy as a quantity which should reappear when the system returns to its initial state.

The production of cast iron and bar iron was rapidly increasing, and the suitability of cast iron and bar iron for the construction of bridges became evident to engineers, among whom Telford was pre-eminent. A distinguished professor, a worker in pure science, came, in the person of Dr. Thomas Young, to the aid of the technical worker. The need of studying the mechanical properties of iron and steel was evident, and Young showed that the work done in permanently extending or in compressing iron or steel could be represented by a coefficient, to which he gave the name of the "Modulus of Elasticity." This coefficient has probably rendered more service in the development of the study of the strength of iron and steel than any other which has been determined. It is of great importance, because upon it depends the deflection which a structure will take under strain. Young, evidently with a view to bring home evidence as to the great rigidity of steel, gives in his original paper a quaint illustration. He therein shows that if "Hook's law holds" a hanging rod of steel would have to be 1500 miles long in order that the upper portions of it might be stretched to twice their original length. I would incidentally point out that on the basis of Young's calculation, such a column 1500 miles high, if it were 1 foot $2\frac{1}{2}$ inches in diameter, would represent the output for the past year of Bessemer steel in this country alone. Statements of this kind had such a singular fascination for Sir Henry, that I have permitted myself a brief departure from chronological order in offering this one.

[The President then referred to the patent granted in 1817 to the Rev. Robert Sterling for the "regenerative furnace," and to the work of S. B. Rogers, who introduced "iron bottoms" in the puddling furnace. An interesting fact was mentioned which justified the claim made in the address, that Rogers was the pioneer of the great process afterwards known as the "basic" process of dephosphorisation. Faraday's work on alloys in 1820, and his discovery of "a carburet of iron" in 1822 was then described, and the merits of Neilson's discovery of the "hot blast" in 1828 were fully dealt with. After a brief reference to the work of Thomas Andrews, of Belfast, on the "heat of combination," the President proceeded to review the theories of the action of the blast-furnace, and especially referred to the work done in the year 1846.]

It was pointed out in 1846 that in the blast-furnace there was evidently a kind of tidal ebb and flow in the relations of carbon and of oxygen, resulting sometimes in reduction, and at others in oxidation or carburisation; but the changes were all capable of more or less simple expression if viewed either from the atomic or the dynamic standpoint. As the furnaces grew in dimensions, their flaming tops threw a lurid glare over the country, and, "like the dying sunset kindled through a cleft," revealed the magnitude of the problems involved in blast-furnace practice, which were seen to be disproportionate to their apparent simplicity.

In the first half of the century efforts were directed mainly to obtaining a material—cast iron containing some $3\frac{1}{2}$ per cent. of carbon, and fusible at a temperature readily attained in the blast-furnace. In the second half of the century, while efforts to obtain this fusible material were increased, attention was also directed to removing the carbon, and obtaining a product which had a melting point of 400° C. (720° F.) higher than

cast iron. This product was either cast directly into ingot moulds or recarburised to the extent necessary to constitute the various gradations of steel. Sheffield hardly knew steel except as a material to be used for the manufacture of cutlery, for which she had been famous since the time of Chaucer.

It is characteristic of our British methods that special circumstances and needs, mainly arising in connection with the development of the steam engine and railways, revealed the broad principles by which the production of iron must be governed. It was natural, therefore, as time went on, that in the work of successive inventors the guidance of scientific principles became progressively evident as ill-directed efforts were gradually replaced by the results of systematic experiments.

The second half of the century began with events of strange importance. The Great Exhibition revealed our industrial strength to all nations. The official reporter of the metallurgical group states that 2,250,000 tons of pig iron were annually produced in this country, and that its estimated value was 5,400,000*l.* The annual production had risen in fifty years from two hundred thousand tons to over two and a quarter millions. Sheffield produced at the opening of the century 35,000 tons of steel, of which 18,000 tons were cast steel. Messrs. Turton exhibited a single ingot of steel weighing 2688 lbs., but Krupp showed an ingot of double the weight, for our country was only preparing for the great change which was so soon to enable it to lead the steel manufacture of the world.

A noteworthy feature of the Exhibition was the collection of iron ores of this country exhibited by Mr. Blackwell, who subsequently, and most generously, provided funds for their analysis. With reference to this collection, the reporter points out that in this country "the ores are not carried far, except where there is great facility for transport." This is noteworthy, as before the century was much older an important supply of ore was brought from Spain, and in the near future we may even seek a supply for British furnaces from distant parts of our own empire.

The year 1851 was, moreover, an important one for metallurgy in this country, as it saw, by the wisdom of H.R.H. the Prince Consort, the establishment of the institution which developed into the Royal School of Mines. If the projected scheme of instruction had been fully carried out, the establishment of a general system of technical instruction, which the pressure of necessity is slowly forcing upon us, would have been anticipated by forty years.

The year 1856 will be ever memorable in the metallurgical annals of our nation as that in which Bessemer gave the description of his process to the world at the Cheltenham meeting of the British Association. As regards the process itself, we have too lately lost our great countryman, and many of us are too familiar with the details of his labours to be able either to fully estimate its value or to realise the wonder of its results. Let us try to think of the Bessemer process as I believe those at the end of the twentieth century will, whose views range over a wider perspective than we can command. The economic aspect of the question will naturally strike the metallurgists of the twentieth century. They will see that in 1855 the make of steel in Great Britain did not exceed 50,000 tons, and the cost of the steel produced sometimes reached 75*l.* a ton. They will see that thirty years after the publication of Bessemer's paper the production of Bessemer steel rose to 1,570,000 tons, and that ship plates were sold at 6*l.* 10*s.* a ton. It will be noted that before the century closed, the maximum production of Bessemer steel in this country in one year reached 2,140,000 tons. The scientific aspect of the process will, however, excite their widespread interest, for before the end of the twentieth century, metallurgy will be taught in our older universities. It will be seen that, notwithstanding the title of Bessemer's Cheltenham paper, he recognised and insisted on the fact that the intense heat was engendered by the combustion of the elements within the fluid bath. It will be noted in what close relation the purely scientific work of Thomas Andrews of Belfast, on the heat of combination, stands to that of Bessemer, and that another instance is presented of the dependence of industrial work on pure investigation. Bessemer's proposal to employ a mixture of steam and air will not be ridiculed as it has been, for speculation will be rife as to whether he did not hope that the liberated hydrogen might remove sulphur and phosphorus, notwithstanding the feebly exothermic result of the ensuing combination, and in spite of the cooling effect of water vapour. In view of the fact that

endothermic combinations take place at a high temperature, the possible action of hydrogen as a decarburiser will be dwelt upon. Prof. Noel Hartley's papers upon the thermo-chemistry of the Bessemer process will be read with much interest. Surprise will, however, be widely felt that physicists generally of the last half of the nineteenth century did not see in the lovely flames of lilac, amethyst, gold, and russet, or in the "stars suspended in a flying sphere of turbulent light" which come from the converter, an appeal to fully investigate their cause and to study the dynamic problems presented by the intense heat engendered. Why was not the destination ascertained of the 1000 cubic feet of argon which accompanies the air passing through the metal during an ordinary Bessemer 10-ton blow? Why were not more strenuous efforts made to ascertain the effect of the temperature of the bath on the nature of the metal?

It will be felt that, as the eighteenth century had closed with a clear statement as to the true nature of oxidation, the nineteenth century had seen its magnificent application in the Bessemer process.

As regards the work of Mushet, future generations will, I believe, desire to add nothing to the words of the President of this Institution who, in 1875, had the pleasure of awarding the Bessemer Medal to him. Mr. Menelaus then said "that the application of spiegeleisen . . . was one of the most elegant as it certainly was one of the most useful inventions ever made in the whole history of metallurgy."

Attention must now be directed to the great process for the production of steel which involved the use of the "open hearth."

Sir William Siemens' life was one long and ultimately brilliantly successful effort to apply the kinetic theory of gases and the dynamical theory of heat to industrial practice. He was eminently a practical worker; but the depth and accuracy of his scientific knowledge gives him a place near that of all the great atomists from the time of Lucretius to that of our own countrymen, Graham, Joule, Clerk Maxwell, and Kelvin. In many of Siemens' papers, theory and practice are closely blended. In viewing the results of his labours, it will be seen in future ages that confidence in the trustworthy character of steel was finally established by experiments on metal produced in the regenerative furnace of Siemens. Looking back, it is astonishing with what difficulties the use of steel for structural purposes was beset. In 1859 Sir John Hawkshaw was not permitted by the regulations of the Board of Trade to employ steel in the construction of the Charing Cross bridge. Time will not permit me to indicate the efforts which were made to induce the Board of Trade to remove the serious hindrances to the use of steel, which had "rendered the construction of the projected bridge over the Firth of Forth practically impossible." These efforts were not successful until 1877, when a committee, consisting of Sir John Hawkshaw, Colonel Yolland, and Mr. W. H. Barlow, were able to recommend that the employment of steel in engineering structures should be authorised by the Board of Trade. The steel employed was to be "cast steel, or steel made by some process of fusion, subsequently rolled or hammered"; one condition of such recommendation being that "the greatest load which can be brought upon the bridge or structure, added to the weight of the superstructure, should not produce a greater strain in any part than $6\frac{1}{2}$ tons per square inch."

As regards the use of steel for shipbuilding purposes, in the year 1875 Sir Nathaniel Barnaby asked, "What are our prospects of obtaining a material which we can use without such delicate manipulation, and so much fear and trembling?" He partly answered his own question four years later, when he quoted experimental evidence as to "the recent successes" of open-hearth steel. In 1890 he completed the case by pointing out that naval architects now "have a perfectly regular material, stronger and more ductile" than iron, and he speaks of "our lasting debt of gratitude for the birth and training of that true prince, William Siemens." It is hardly necessary to point out that the country owes the excellent materials used in naval architecture mainly to the productions of the regenerative furnace.

In connection with the production of mild steel, the addition of ferro-manganese to the decarburised bath proved to be most effective. We can hardly over-estimate our indebtedness to those whose perseverance ensured the adoption of mild steel for maritime and other purposes. "Looked at from the standpoint of to-day, when thousands of tons of such steel are made weekly without serious anxiety or trouble, it is scarcely possible to

realise the anxieties and difficulties of the days when the manufacture of open-hearth steel was being perfected." To no one is our debt greater than to our Vice-President, Mr. James Riley, who bore a large share of the anxieties of the early days, and whose words are those I have just quoted.

With regard to the great modifications which have been effected in the Bessemer and open-hearth processes, reference must be made to that ample source of information, our *Journal*. It must also be consulted for the history of the appliances for heating the blast, with which the names of Cowper and of Whitwell will always be specially connected.

In speaking of Bessemer and Siemens I have been obliged to depart somewhat from strict chronological order. I must now resume it.

In the year 1866 Graham's first paper on the occlusion of gases by metals was published in the *Philosophical Transactions*. Its results have been far-reaching, and will always be ranged with the metallurgical triumphs of the century.

In the year 1869 our Institute was founded. In view of certain aspects of the treatment which inventors had previously received from their industrial brethren and from the country, it will be evident that the time for its formation had fully come. Taking instances almost at random, I may remind you that Dud Dudley was, as he says, "with lawsuits and riots wearied and disabled" in the seventeenth century, and that Henry Cort was neglected and oppressed in the eighteenth. The great invention of iron bottoms in the puddling-furnace made by Rogers was received with ridicule, and he died in poverty. Popular tradition of Sheffield indicates that possession was obtained of Huntsman's secret "by the heartless trick of a rival." Neilson, though he warmly acknowledges the support he received from certain ironmasters, was treated with singular meanness by others. Heath fought single-handed for fifteen years "against a common purse, the accumulation of the wealth which he had created." Even Bessemer's early statements were received with incredulity and contempt. With the formation of our Institute all this is changed: men place the results of their work and experience freely at the disposal of their brethren, and each fresh advance meets with appreciative consideration. "Vigorous moderateness," wrote the late Walter Bagehot, "is the rule of a polity which works by discussion. . . . It was government by discussion that broke the bond of ages and set free the originality of mankind."

[It was then pointed out, that the history of the iron and steel industry since the formation of this Institute was epitomised by the labours of those who had occupied the presidential chair. The President, therefore, gave a brief sketch of the work done either by the successive Presidents of the Institute, or during their respective terms of office.]

The address then continues as follows: This concludes the list of those who have hitherto presided over the Institute, and it will have been evident that from time to time other interests than those connected with iron and steel have been represented by your Presidents. We were reminded of this fact when the Institute first met, now twenty-four years ago, at Manchester, where we are promised a delightful meeting again next autumn. The Bishop of that great city then welcomed us by a quotation from Virgil, which connects the age of iron with the age of gold. The passage runs thus:—

"quo ferrea primum
Desinet ac toto surget gens aurea mundo."

A President of this Institute who has had the privilege to serve in the Mint, in a sense connects the iron and the golden age. I find that during the course of a long official career I have been responsible for the standard fineness of over one hundred and twenty-one millions of gold coin. This sum is so vast, and the anxiety connected with it has been at times so great, that I am not careful to conceal the pride revealed by this reference to it, as it is an exponent of the financial greatness of the nation which created the age of steel. But I value as highly the means of conducting research and the hope of being useful, which was also given me by the Government when I was appointed Professor of Metallurgy at the Royal School of Mines. I have in the discharge of my duties persistently striven to show that what is called applied science is nothing but the application of pure science to particular classes of problems.

I regret that space will not permit me to consider the progress of the century as measured by the work of our Bessemer medallists. I hope, however, as regards the labours of the foreign recipients of the honour, to deal with them next spring.

The metallurgy of America is so closely interwoven with our own, that I must permit myself a brief reference to four men who stand out from the industrial ranks of our kinsmen. These are Alexander Lyman Holley, the Hon. Abram S. Hewitt, John Fritz, and Prof. Henry Marion Howe. All of them are Bessemer metallists.

It may help us to estimate the value of the labours of the four men whose names I have given if we remember that at the present time the United States export about a million tons of iron and steel a year, while twenty years ago they were not exporting any. We may also fairly consider their influence on the rapid development of the United States Navy. It would seem that we, in this country, in the belief in our insular security, had somewhat neglected the art of naval warfare, until Admiral Mahan reminded us of what we had done in the past, and of our possible course in the future, in a series of writings which have done much to convince the two nations, England and America, "that they are in many ways one."

It is time to offer a collective statement of the achievements which have either been actually effected or are in immediate prospect.

There are blast-furnaces which will produce 748 tons of pig iron in twenty-four hours, with a consumption of little over 15.4 cwt. of coke per ton of iron. The gases from blast-furnaces are used, not only as sources of heat, but directly in gas-engines.

There are Bessemer converters which can hold 50 tons of metal, and open-hearth furnaces which will also take 50 tons, while 100-ton furnaces are projected. The open-hearth furnaces are fed with one ton of material in a minute, by the aid of a large spoon worked by an electro-motor. There are gigantic "mixers," capable of holding 200 tons of pig iron, in which, moreover, a certain amount of preliminary purification is effected.

Steel plates are rolled of over 300 feet in area and 2 inches thick. There are girders which justify the belief of Sir Benjamin Baker that a bridge connecting England and France could be built over the Channel in half-mile spans. There are ship-plates which buckle up during a collision, but remain water-tight.

There are steel armour piercing shot which will penetrate a thickness of steel equivalent to over 37 inches of wrought iron. The points of the shot remain intact, although the striking velocities are nearly 2800 feet a second. There are wires which will sustain a load of 170 tons per square inch without fracture. Hadfield, whose labours will, I trust, be continued far into the twentieth century, has given us manganese-steel that will not soften by annealing; while Guillaume has studied the properties of certain nickel steels that will not expand by heat, and others that contract when heated and expand when cool. Nickel, chromium, titanium, and tungsten are freely used alloyed with iron, and the use of vanadium, uranium, molybdenum, and even glucinum, is suggested. There are steel rails which will remain in use seventeen years, and only lose 5 lbs. per yard, though fifty and a half million tons of traffic have passed over them.

Huge ingots are placed in soaking pits and forged direct by 120-ton hammers, or pressed into shape by 14,000-ton presses. With such machinery the name of our late Member of Council, Benjamin Walker, will always be connected.

There are steel castings, for parts of ships, that weigh over 35 tons. We electrically rivet and electrically anneal hardened ship-plates that could not otherwise be drilled. Photomicrography, originated by Sorby in 1864, now enables us to study the pathology of steel, and to suggest remedial measures for its treatment. Stead's work in this field is already recognised as classical. Ewing and Rosenhain have, in a beautiful research, recognised quite recently by its aid that the plasticity of a metal is due to "slip" along the cleavage planes of crystals. Osmond also by its aid shows that the entire structure of certain alloys may be changed by heating to so low a temperature as 225° C.

Passing to questions bearing upon molecular activity, we are still confronted with the marvel that a few tenths per cent. of carbon is the main factor in determining the properties of steel. We are, therefore, still repeating the question, "How does the carbon act?" which was raised by Bergman at the end of the eighteenth century. Nevertheless, from the molecular point of view, much may be said in answer to the question. The mystery is in fact lessened now, as it is known that the mode of existence of carbon in iron follows the laws of ordinary saline solutions. Our knowledge is, however, of very recent origin,

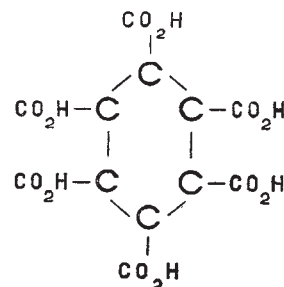
and we owe mainly to the Alloys Research Committee of the Institution of Mechanical Engineers the development of Matthiessen's view that there is absolute parallelism of the solution of salt in water and carbon in iron.

An ice-floe in a Polar sea contains a small percentage of salt; a red-hot ingot of mild steel holds some two-tenths per cent. of carbon, but both the carbon and the salt are in the state of *solid* solution. If the ice had been cooled below -18° C., it would entangle a solidified portion of salt water, which was the last part of the mass to remain fluid. So in the steel ingot, when it has cooled to the ordinary temperature, there is a solidified "mother liquor" of carburised iron. We do not as yet know whether carbon is dissolved in fluid iron as carbon or as a carbide. We do know, however, that the presence of 0.5 per cent. of carbon in iron (such an amount as might occur in a steel rail) lowers the melting point of the iron from 1600° C. to 1530° C. This lowering has enabled a calculation to be made, the result of which shows that the number of atoms in a molecule of carbon in *fluid* iron at this temperature is probably *two*. It can be shown that at a temperature of 800° C. the number of atoms in the molecule of carbon dissolved in *solid* iron is, in all probability, *three*. At lower temperatures, the number of atoms is probably more than three. We metallurgists are not accustomed to think in atoms. Let me, therefore, represent such a three-

atom molecule thus,  without assuming how much

iron is associated with the carbon. Following Bergman's experimental method, but with the interval of more than a century separating his work from ours, we investigate the action of acids on carburised iron with a view to ascertain the nature of the atomic grouping of the carbon.

In explaining this, I may adopt the appended figure. It is most difficult even to attempt to make questions of atomic grouping clear in a paragraph, but the figure will be helpful. To the historian it suggests vivid pages of Italian history, as the six spheres so arranged constitute the arms of the powerful family of Medici. To the chemist it is a precious symbol, and appeals to him as representing the carbon atoms as grouped in the benzene ring. The result of treating carburised iron with various acids is the formation of marsh-gas and more complicated organic compounds, of which propylene, acetylene, ethylene, and naphtha may be mentioned. Does the nature of these products help us to ascertain the number of the atoms in the carbon molecule as it exists in cold steel? I have consulted organic chemists, among whom I would specially mention my colleague Dr. Wynne, and their evidence is encouraging. The result of the action of powerful oxidising agents on certain forms of carbon is mellitic acid, $C_6(CO_2H)_6$, which is one of the benzene series, and this favours the view that solid carbon contains twelve, or some multiple of twelve, atoms in the molecule. But mellitic acid is graphically represented in the annexed diagram, the carbon



atoms being arranged as the six spheres are in the arms of the Medici. The group CO_2H is tacked on to each carbon sphere. From this it may be argued that the molecule of solid carbon consists of one or more carbon "rings." In cold steel, the group of CO_2H may be replaced by the group Fe , which is broken off by the action of suitable solvents leaving free carbon. Hence the six-atom carbon molecule may exist in steel.

My object is merely to show you how far at the end of the century we have advanced in our knowledge of the mode of action of carbon, and I trust it will be evident that the progress is remarkable. We know that even in solid iron the carbon atom must push and thrust with great vigour, for we can measure the "osmotic pressure" the carbon atom exerts, and, as has just been shown, we can even picture the mode of the atomic grouping in the molecule.

I can only just sum up the evidence as to the occurrence of molecular change in iron. To Gore, and to Barrett, we owe the investigation of the nature of a fact which had long been well known to smiths, that iron on cooling from a bright red heat suddenly emits a glow. We now know that as steel cools down there may be at least six points at which molecular change occurs, accompanied by evolution of heat.

In a series of classical papers of which we are justly proud, for many of them have been communicated to this Institute, our member, Osmond, has shown what is the significance of some of these points, and has won an enduring reputation. We measure and record them photographically as readily as if they were barometric variations. It is known that three points occur in the purest electro-iron yet prepared. Two points are connected with the magnetic permeability of iron. One point at least is due to the power iron has of dissolving carbon. In some cases, two points occur far below a red heat, and appear to be due to the presence of hydrogen. Moreover, the molecular condition of steel cooled from an intense white heat is not the same as that of steel which has just been melted. To carry further the evidence as to the effect of an intense heat on iron in a vacuum is the task I have in prospect during my presidency of the Institute. I may, however, express my agreement with Lockyer's view that the evidence afforded by the atmosphere of the stars shows that our terrestrial iron is a very complex form of matter.

We must not lose sight of those relations of carbon and iron which involve physical equilibrium. Even the astonishing associations of iron and carbonic oxide in the volatile gaseous compound with which the distinguished name of Mond is connected affords a triumph of dynamic chemistry. It is generally supposed that ozone is dissociated at 160° C., but Dewar has devised a beautiful experiment to prove that ozone has two centres of stability, and one of these is near the melting point of platinum. It seems to be the same with the relation of hydrogen and iron. We have recently learned that iron and hydrogen appear to be completely dissociated at 800° C., and yet the same iron heated to some higher temperature, say 1200° C., will still yield hydrogen.

Let us suppose that Black, Cort, and Bergman were with us again, and had reviewed the present state of our knowledge and the work accomplished in the century. Let us also suppose that they could go to Sheffield and see an armour-plate rolled and finished for service, and then, visiting our Institute, hear the best explanation we could offer of all the incidental phenomena they had witnessed. Which would they consider the more advanced, our practice or our theory? They would probably hesitate to tell us, but would offer warm congratulations on the immediate prospect of the establishment of a National Physical Laboratory, in which investigations as to the properties of iron and steel will be continued.

THE IRON AND STEEL INSTITUTE.

THE annual meeting of the Iron and Steel Institute was held on May 4 and 5 at the Institution of Civil Engineers. The chair was occupied at the beginning of the proceedings by Mr. E. P. Martin, the retiring president. The report of the Council was read by the secretary, Mr. Bennett Brough, and showed that during the year 98 new members had been elected, and that the Institute had maintained its prosperous and satisfactory condition. Sir William Roberts-Austen then took the presidential chair, and delivered an inaugural address, which is printed in an abridged form in another part of this issue. A vote of thanks to the president for his address was proposed by Sir Bernhard Samuelson, seconded by Sir William H. White, and carried by acclamation.

The first paper read was by Mr. H. Bauerman on the Gellivare iron mines, the important mineral region situated in 67° 11' North latitude and 20° 11' East longitude. The paper

gave a detailed geological description of the mineral deposits, and formed a valuable supplement to previous descriptions of these mines. In the discussion which followed, Mr. W. Whitwell pointed out the importance of this Swedish source of supply in view of the approaching exhaustion of the Spanish deposits, and Mr. H. G. Turner remarked on the similarity of some extensive magnetite deposits in Southern India.

Mr. A. P. Head read a paper on tilting open-hearth furnaces which are coming into use in the United States, and present a substantial advance in metallurgy likely to have far-reaching effects in the future of the relative positions of the Bessemer and open-hearth processes. An interesting discussion followed, in which Mr. Wellman, of Chicago, and Mr. R. M. Daelen, of Düsseldorf, took part.

Prof. Henry Louis then described a dipping needle he had devised for use in exploring for iron ore deposits, which presented decided advantages over the instruments described by Mr. B. H. Brough in 1887, and by Prof. Nordenström last year.

A paper by Prof. J. Wiborgh, of Stockholm, on the use of hot blast in the Bessemer process, was then taken as read. In this the author urged the advantages that would be derived from the use of the hot blast for small converters and for the basic Bessemer process.

The meeting then adjourned until May 5, when a paper by Prof. J. O. Arnold and Mr. A. McWilliam on the diffusion of elements in iron was read. An animated discussion followed, in which Mr. Stead, Mr. Hadfield, Mr. Harbord, Dr. Stansfield and Prof. Louis took part.

A voluminous paper by Baron Jüptner von Jonstorff, on the solution theory of iron, was taken as read. In two previous communications he sought to apply the laws of solution to iron and steel, and in this third paper he carries the research further. He finds that carbon is dissolved as such in pure iron by a sufficiently high temperature. The molecule of the dissolved carbon between 1600° and 1300° C. consists of two atoms. It increases with decreasing temperature, and at 1150° C. nearly equal amounts of two and three atom molecules are present in the solution. At a still lower temperature, there is in the solution, besides a certain amount of free carbon increasing with the content of carbon present, iron carbide. At first the latter remains in solution with the free carbon (austenite). If, however, its quantity increases above a certain amount, the alloy separates into two parts. In the one the free carbon prevails, in the other the carbide of iron (martensite) prevails. With falling temperature, the amount of the iron carbide increases, as also does the martensite, whilst the quantity of the austenite decreases until at length only martensite is present.

Mr. Enriqué Disdier contributed a paper on the use of blast-furnace and coke-oven gases, in which he urged that coke-oven gases should be heated by blast-furnace gases and the oven gases used for driving gas engines. By the adoption of this method of utilising the gases, the cost of pig-iron would, he asserts, be reduced by 5s. 5½d. per ton. In the discussion, Mr. James Riley expressed the opinion that the author had worked out his case well, but considerable difficulties would have to be surmounted before his theory was put into practice. Mr. Hugh Savage described the progress that had been made in Belgium in the use of blast-furnace gases as motive power. Mr. Charles Wood and Mr. Enoch James anticipated difficulty from the dust in the gases.

Mr. Bertrand S. Summers, of Chicago, contributed a lengthy paper on theories and facts relating to cast-iron and steel. In the discussion, Mr. R. A. Hadfield expressed the opinion that there was a demand among electricians for material of high permeability and of low cost, and he thought that the author had done much to render this possible. Mr. W. Mordy also discussed the paper from the electrician's point of view.

The last paper on the list was from the pen of the great Russian metallurgist, Mr. D. Tschernoff. It described a construction of blast-furnace in which gas is used in lieu of solid fuel, and in which iron or steel may be produced direct from the ore.

The usual votes of thanks were carried, and the meeting, which throughout was largely attended and most successful, was declared at an end. On the evening of May 4, the annual dinner was held at the Hotel Cecil, and on May 5 the members were entertained by Sir William and Lady Roberts-Austen at their residence in the Royal Mint.